Video Article

Computerized Dynamic Posturography for Postural Control Assessment in Patients with Intermittent Claudication

Natalie Vanicek[1,2], Stephanie A. King[2], Risha Gohil[2,3], Ian C. Chetter[3], Patrick A Coughlin[3,4]

[1]Discipline of Exercise and Sport Science, Faculty of Health Sciences, University of Sydney

[2]Department of Sport, Health and Exercise Science, University of Hull

[3]Academic Vascular Department, Hull Royal Infirmary, Hull and East Yorkshire Hospitals

[4]Department of Vascular Surgery, Addenbrookes Hospital

Correspondence to: Natalie Vanicek at natalie.vanicek@sydney.edu.au

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Abstract

Computerized dynamic posturography with the EquiTest is an objective technique for measuring postural strategies under challenging static and dynamic conditions. As part of a diagnostic assessment, the early detection of postural deficits is important so that appropriate and targeted interventions can be prescribed. The Sensory Organization Test (SOT) on the EquiTest determines an individual's use of the sensory systems (somatosensory, visual, and vestibular) that are responsible for postural control. Somatosensory and visual input are altered by the calibrated sway-referenced support surface and visual surround, which move in the anterior-posterior direction in response to the individual's postural sway. This creates a conflicting sensory experience. The Motor Control Test (MCT) challenges postural control by creating unexpected postural disturbances in the form of backwards and forwards translations. The translations are graded in magnitude and the time to recover from the perturbation is computed.

Intermittent claudication, the most common symptom of peripheral arterial disease, is characterized by a cramping pain in the lower limbs and caused by muscle ischemia secondary to reduced blood flow to working muscles during physical exertion. Claudicants often display poor balance, making them susceptible to falls and activity avoidance. The Ankle Brachial Pressure Index (ABPI) is a noninvasive method for indicating the presence of peripheral arterial disease and intermittent claudication, a common symptom in the lower extremities. ABPI is measured as the highest systolic pressure from either the dorsalis pedis or posterior tibial artery divided by the highest brachial artery systolic pressure from either arm. This paper will focus on the use of computerized dynamic posturography in the assessment of balance in claudicants.

Video Link

The video component of this article can be found at http://www.jove.com/video/51077/

Introduction

Computerized dynamic posturography (CDP) is an assessment technique to measure postural control objectively. It isolates and quantifies the functional contributions of different sensory systems (*i.e.* somatosensory, visual and vestibular input) and the mechanisms for integrating these sensory input for maintaining balance. It is a valuable tool for investigating sensory, motor and central adaptive impairments[1]. Computerized dynamic posturography detects postural sway by measuring shifts in the center of gravity (COG) as a person moves within their limits of stability. It can quantify postural strategies to static and dynamic perturbations, by determining whether an individual uses an ankle or hip strategy during the CDP protocols, or a combination of the two, in response to postural disturbances.

Balance assessments are routine in clinical and rehabilitation settings. They provide an indication of a person's ability to control their balance under different conditions, such as reduced base of support (*e.g.* tandem or unilateral stance) or without visual input (*e.g.* eyes closed). Thus they are often used to determine an individual's susceptibility towards falling. Several validated and reliable balance tests, such as the Berg Balance Scale[2] and the Tinetti Gait and Balance test[3], are commonly used clinically to evaluate an individual's ability to maintain balance during functional tasks. While the tests were designed primarily for use with older people, they are also subjective, and liable to ceiling effects, especially among community-dwelling elderly with high levels of functioning. Computerized dynamic posturography with the EquiTest provides an objective assessment of postural control and thus requires the use of more complex equipment than routine clinical tests. However, it is also more costly and not portable. Thus, it is intended to complement, not replace, existing clinical measures that categorize the mechanisms of balance disorders.

Intermittent claudication, a frequently reported symptom of peripheral arterial disease, is characterized by a cramping pain developed in the lower extremities during physical activity and relieved with rest. Claudicants have impaired balance and gait; they exhibit functional limitations and are susceptible to falling. Ankle brachial pressure index (ABPI) is a simple, noninvasive method for detecting the presence of peripheral arterial disease with intermittent claudication concomitant with impaired lower limb function. The disease is commonly treated noninvasively with lifestyle and exercise programs[4]. The early detection of postural impairments is beneficial for the effective prevention of falls[1]. Whilst measuring the ABPI is not necessary for patients without symptoms of peripheral arterial disease with intermittent claudication, or for patients with other balance-related dysfunction, it is important as part of a complete medical examination in patients where peripheral arterial disease is suspected and movement and balance are affected adversely.

Computerized dynamic posturography, with protocols such as the Sensory Organization Test and Motor Control Test on the EquiTest, has been used in studies investigating balance in healthy older adults[5], to differentiate between elderly fallers and nonfallers[6], in individuals with balance disorders[7] and even with transtibial amputee populations[8,9]. Computerized dynamic posturography has been assessed previously with a claudicant population, and results have indicated that 52% of claudicants exhibit vestibular dysfunction[10] and perform significantly worse with increasing claudication severity[11]. Thus this objective balance measurement technique is deemed sensitive enough to differentiate postural control strategies in patients according to disease severity. This paper will focus on the use of computerized dynamic posturography in the assessment of balance in patients diagnosed with intermittent claudication caused by peripheral arterial disease.

Protocol

Participants were outpatients of a vascular surgical unit at a local teaching hospital and gave informed consent to participate in this study. The study was approved by the NHS Local Research Ethics Committee (REC reference: 07/Q1105/12) and the protocol complied with the IRB guidelines of the University of Hull. All participants completed the Sensory Organization Test and Motor Control Test on the EquiTest. Ankle brachial pressure index was measured preexercise to categorize disease severity.

1. Ankle Brachial Pressure Index (ABPI) Measurement

1. Allow the participant to rest in the supine position for at least 5 min before the ABPI measurement is taken.
2. Adjust a standard sphygmomanometer cuff over the brachial artery above the elbow and the dorsalis pedis and posterior tibial arteries above the ankle. Rapidly inflate the cuffs to 20 mmHg above the audible systolic pressure before deflating at a constant rate of 2 mm/sec.
3. Record the systolic pressure as the pressure at which the first sustained systolic pressure is audible. Then using a hand-held Doppler probe (5-8 MHz), measure the systolic pressures of the dorsalis pedis and posterior tibial arteries.
4. Calculate ABPI with ankle systolic pressure as the numerator, over the brachial systolic pressure as the denominator.

Note: There are several methods currently used to determine the numerator value of the ABPI. The American Heart Association advocates using the higher systolic pressure of the two leg arteries for the numerator[12] which is what we used, while another method reported in the literature states using the lower systolic pressure[13]. A third method recommends using the average systolic pressure from the dorsalis pedis and posterior tibial arteries[13].

2. Equipment Setup

1. Ensure the area surrounding the EquiTest is free of obstructions and remove any object from the dual force plates and turn on the EquiTest system. Complete the dual force plate support surface and visual surround calibration.

   Note: Movement of the force plates occurs along an x- and y-axis. The dual force plates first translate forwards and backwards about the y-axis, which is parallel to the floor, at a maximum linear velocity of 15.24 cm/sec. They then rotate about the x-axis, so as to facilitate ankle dorsiflexion (toes up) and plantarflexion (toes down), at a maximum angular velocity of 50°/sec (0.87 rad/sec). The visual surround tilts forwards and backward about the x-axis at a maximum angular velocity of 15°/sec (0.26 rad/sec) across a range of ±10°. Four force transducers in two independent force plates measure vertical forces for each limb; a fifth transducer, beneath the pin joint that connects the two force plates, measures shear force overall.
2. Enter the participant information (*e.g.* age and height) into the software program. Indicate their age and height accurately.

   Note: The participant's results will be compared against an age-matched normative dataset (20-59, 60-69, 70-79 years). Height will allow for the magnitude (small, medium, and large) of the backwards and forwards force plate translations to be scaled according to their height.
3. Choose whether to turn the display screen within the visual surround on or off.

   Note: If the display screen is turned on, the participant will get real-time visual biofeedback about their COG movement, which may be useful for practice sessions or when the operator wants the participant to see their score. The results from each trial are processed upon completion of the trial and displayed as green or red bars. Green bars indicate the participant performed better than the age-matched normative data, while red bars indicate their performance was worse.

3. Participant Preparation

1. Request that the participant wears comfortable loose clothing and removes their shoes for tests on the EquiTest. Have the participant put on the safety harness, while securing the long straps through their legs and fastening the waist buckle.
2. Position the participant onto the dual force plates and clip the karabiner from the safety straps into the D-rings of the security harness.

   Note: The participant is now securely fixed to the safety bar (via the safety straps) which will prevent them from actually falling, should they lose their balance (or feel like they are going to lose their balance) during the testing.

3. Center the participant's feet on the support surface: position the medial malleolus of each foot over the blue horizontal line, so that the ankle joint is aligned with the transverse rotational axis, and position the lateral side of the calcaneous according to the S, M, or T surface markings. Adjust the tension on the safety straps so they are neither too slack nor too taught.

   Note: According to the participant's height, small ranges from 76-140 cm, medium from 141-165 cm, and tall from 166-203 cm (**Figure 1A**). Backwards and forwards movements of the support surface (dual force plates) occur along the y-axis, while side to side movements on the support surface occur along the x-axis. The dual force plates can rotate about the x-axis, which represents the transverse axis of the ankle joint. When the participant is standing with ankles over the blue horizontal line and with feet equidistant laterally from the center line (y-axis) according to the S, M, or T markings, their center of gravity should be located directly above the x- and y-axis intercept. This position acts as a reference point for the calculation of sway angles
4. Ask the participant to stand upright, with their hands at their sides, looking straight ahead at the visual surround. Request they refrain from moving their feet for the duration of the test (**Figure 1B**).

   Note: If the feet are correctly positioned, the center of gravity (COG) display should illustrate the stick figure at the intersection of the x- and y-axis. However, if the stick figure is misaligned and the feet are correctly positioned (according to the instructions above), do not readjust the feet.

4. Sensory Organization Test (SOT)

1. Complete Conditions 1-6 on the SOT protocol.

   Note: The SOT consists of 6 conditions, each comprised of 3 trials lasting 20 sec each. In Conditions 1 and 2, the participant stands quietly with eyes open and closed, respectively. This establishes whether sway increases when visual cues are removed and determines how effectively the participant makes use of somatosensory input. In Condition 3, the participant stands with their eyes open; the visual surround is sway-referenced and visual cues become inaccurate. In Condition 4, the support surface is sway-referenced; thus somatosensory cues become inaccurate. Condition 5 is performed with eyes closed and a sway-referenced support surface. This determines how the participant makes use of vestibular cues when visual cues are removed and somatosensory cues are inaccurate. Finally, in Condition 6, the visual surround and support surface are both sway-referenced, which identifies if the participant relies on visual cues even when they are inaccurate. The SOT conditions are graded in difficulty. The first 3 conditions are performed on a static support surface, while the last 3 conditions use a dynamic support surface.
2. Evaluate the score after each trial (a green or a red bar will appear displaying the participant's *Equilibrium score* relative to the age-matched normative dataset). Interrupt any trial at any time if the participant looks like they require assistance.
3. Mark any trial where the participant takes a step, touches the visual surround or starts to fall as a loss of balance (LOB). Allow the participant to rest in between trials if necessary and accurately reposition feet afterwards.

Allow the software to compute the results for the following variables of interest: *Equilibrium score* - an overall indicator of balance; *Strategy analysis* - an indicator of ankle vs. hip strategy dominance; *Sensory analysis* - an indicator of which sensory system is used to maintain balance (*i.e.* somatosensory, visual, vestibular or visual preference); and initial *COG alignment* prior to onset of each trial. *Equilibrium score* is computed according to Equation 1, where 12.5° represents the maximum normal postural sway in the anterior-posterior direction; θ represents the participant's s calculated maximum anterior-posterior COG displacements[14]. A score of 100 represents perfect stability; a score of 0 indicates a loss of balance.

$$\frac{12.5^\circ - (\theta\max - \theta\min)}{12.5^\circ} * 100 \qquad \text{Equation 1}$$

Strategy score represents the peak-to-peak amplitude of the shear oscillation relative to the maximum possible shear force of 25 lbs (11.4 kg), where 25 lbs is the difference between maximum and minimum shear force generated by individuals who only used the hip strategy to maintain balance on a narrow beam (Nashner, unpublished data; cited in EquiTest System Operator's Manual)[14]. A score near 100 indicates a full ankle strategy; a score near 0 indicates a full hip strategy with maximum shear force. The *Sensory analysis* computes four sensory ratios by using the average *Equilibrium scores* from specific pairs of sensory test conditions. These are:

$$\frac{\text{Condition 2}}{\text{Condition 1}} = \text{Somatosensory (SOM)} \qquad \text{Equation 2}$$

$$\frac{\text{Condition 4}}{\text{Condition 1}} = \text{Visual (VIS)} \qquad \text{Equation 3}$$

$$\frac{\text{Condition 5}}{\text{Condition 1}} = \text{Vestibular (VEST)} \qquad \text{Equation 4}$$

$$\frac{\text{Condition 3+6}}{\text{Conditions 2+5}} = \text{Visual Preference (PREF)} \qquad \text{Equation 5}$$

Initial *COG alignment* is determined as the average anterior-posterior COG position in the preceding half second before each SOT trial.

5. Motor Control Test (MCT)

1. Complete all 6 conditions on the MCT, including 3 forwards and 3 backwards translations that are graded in magnitude (small, medium, and large).

   Note: Small translations represent a threshold stimulus, while large translations require the participant to produce a maximal response. Medium translations are in between the two ends of the spectrum. Each condition is performed 3x, with a random delay of 1.5-2.5 sec in between. The horizontal displacement of the support surface during each translation is scaled according to the participant's height.
2. Ensure the feet are positioned precisely on the support surface according to the above instructions. Perform the trials in the standardized order (first backwards, then forwards translations). Interrupt any trial if necessary and record a loss of balance as above.

   Note: The full MCT takes approximately 5-10 min to complete without rests. Allow the software to compute the results for the following variables of interest: *Weight symmetry* - weight bearing distribution in the left vs. right limbs prior to the onset of a translation as measured by the force transducers; *Latency* - time lapse (in milliseconds) between the onset of support surface translation and the participant's active force response, measured for each limb independently; and *Amplitude scaling* (or Relative response strength) - strength of the participant's active force response to arrest the angular momentum imparted to the body during the backwards and forwards translations. The response strength is measured for each leg independently in units of angular momentum (degrees/second) and normalized to body height and weight.

6. Participant Debriefing

1. Assist the participant down from the platform following the completion of the SOT and MCT. Discuss the implications of their findings by explaining how they performed overall on the SOT and MCT.
2. If appropriate, discuss or refer the participant to a balance training program with qualified supervision if they scored poorly on any of the tests. Recommend further medical investigations if the participant scored poorly on any of the sensory scores.

Representative Results

Ankle Brachial Pressure Index (ABPI)

An individual's ABPI can be used to classify the presence of peripheral arterial disease. An ABPI of 1.0-1.2 falls within a normal range. Values from 0.9-1.0 are acceptable, but 0.4-0.9 is indicative of mild to moderate peripheral arterial disease severity. ABPI of <0.4 confirms severe peripheral arterial disease[15]. An ABPI of <0.9 is 95% sensitive and 99% specific for peripheral arterial disease[16] and is associated with leg function in patients with peripheral arterial disease.

Sensory Organization Test

Figure 2 illustrates a typical interpretation of the *Equilibrium score*, *Sensory* and *Strategy analyses* and *COG alignment* from the SOT for one single participant. The green bars indicate the participant performed better than the age-matched normative dataset on conditions 1-4. The participant scored worse than the normative dataset in the last trial for condition 5 and the first trial in condition 6. However, the (green) composite score indicated the participant had a normal *Equilibrium score* overall (**Figure 2A**).

The *Sensory analysis* results can be viewed in **Figure 2B**. The green bars indicate the participant did not have any deficits in the somatosensory (SOM), visual (VIS) or vestibular (VEST) systems and thus was able to make use of these sensory references adequately. The participant was able to discern between accurate and inaccurate visual information and scored better than normative scores on visual preference (PREF).

Strategy analysis results are presented in **Figure 2C**, where each condition (1-6) is indicated as a symbol. Large values (approaching 100 on both axes) indicated the participant used a predominant ankle strategy to maintain balance in those conditions. An ankle strategy is appropriate in response to small perturbations when corrective postural adjustments can be made by generating a small torque about the ankle joint to realign the COG. Conversely, a hip strategy is necessary to generate a larger torque about the hip joint to reposition the COG in response to larger perturbations, whilst a stepping strategy quickly realigns the base of support to the rapidly changing COG. Small values (approaching 0) indicated the participant relied on a hip strategy for that condition. For example, this participant primarily used an ankle strategy in conditions 1-3, and a combination of ankle and hip strategies in conditions 4-6. But the low *Strategy analysis* score for one trial in conditions 5 and 6 indicated the participant's COG was approaching their limits of stability, as they were relying on a hip strategy to generate larger and faster postural corrections about the hip joint. Large horizontal shear forces, indicative of a hip strategy, were necessary to realign the COG in response to more destabilizing postural disturbances. The two low *Strategy analysis* scores correspond to the two red bars in the Equilibrium score.

The x-y plot of the *COG alignment* prior to the onset of the SOT condition is represented by various symbols in **Figure 2D**. Those outside of the white box are considered off-center and indicate under which conditions the participant is more likely to lose their balance if the postural disturbance is in the same direction as the alignment offset. For this participant, their COG alignment was positioned posteriorly and to the right prior to the onset of some SOT conditions (predominantly conditions 5 and 6, represented by the square and right-facing triangular symbols, respectively). This indicated that only small additional displacements were required to cause the participant to approach their limits of stability under those altered sensory conditions (as evidenced by the red bars in **Figure 2A** and greater reliance on the hip strategy in **Figure 2C**).

Motor Control Test

The results for the Motor Control Test are presented in **Figure 3**. *Weight symmetry* values during graded backwards and forwards translations reveal this participant had their weight relatively centered between the right and left legs prior to the onset of the support surface translation (**Figure 3A**). This is evident as a score of 100 indicates perfect between-limb symmetry.

The time lapse between perturbation onset and postural correction is presented in msec in **Figure 3B**. In this case, the participant did not generate a sufficiently quick active force response with the left leg when subjected to medium (M) and large (L) translations in the backwards direction, which explains the presence of the red bars. The '4' at the bottom of each bar specifies the reliability of the *Latency score*; in this case, four (the maximum) algorithms agreed on the same take-off point. The data are considered highly reliable.

Amplitude scaling, or response strength, reflects the participant's ability to generate a response that is in proportion to the perturbation (**Figure 3C**). It is scored in units of angular momentum and normalized to body height and weight. This participant exhibited good symmetry for both legs in the backwards direction, but the response strength was weaker for medium and large translations in the forwards direction, indicating the participant may be less effective at responding quickly to forwards perturbations.

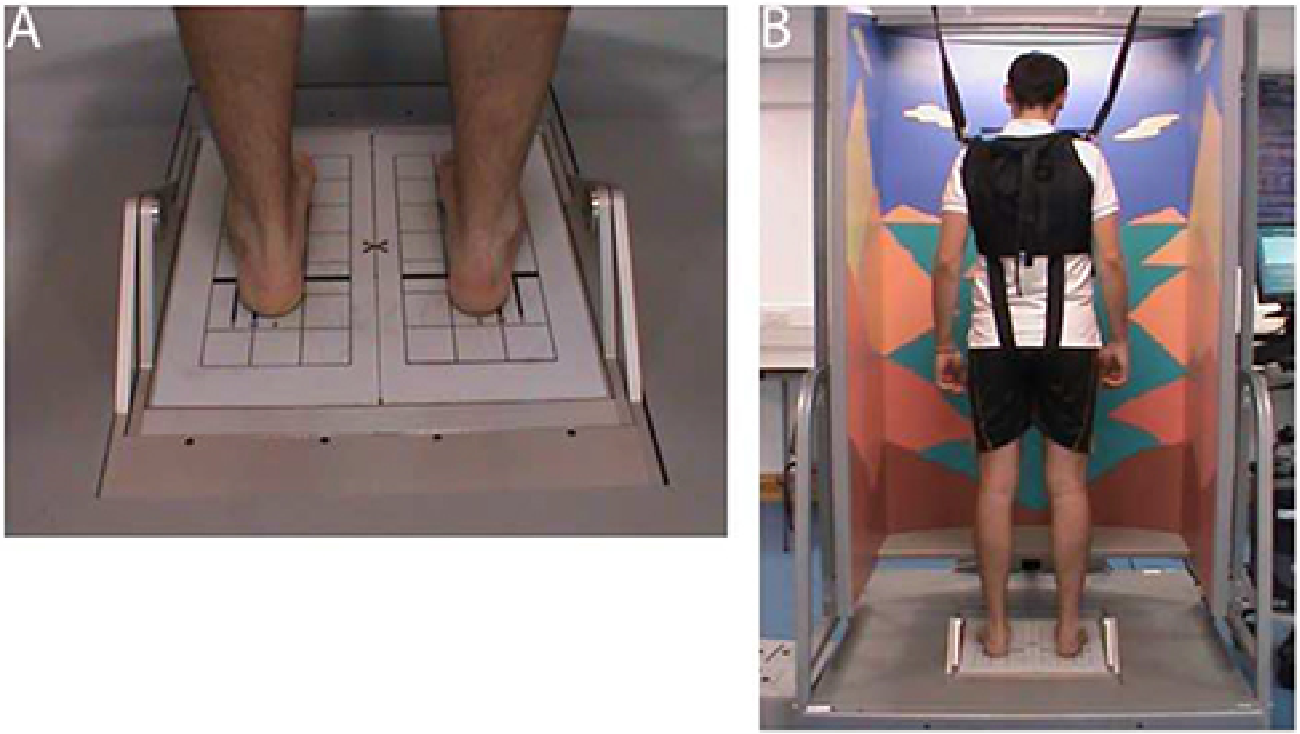

Figure 1. (A) Correct positioning of the feet on the EquiTest. (B) Participant wearing safety harness and standing on the dual force plate support surface, looking at the visual surround. Click here to view larger image.

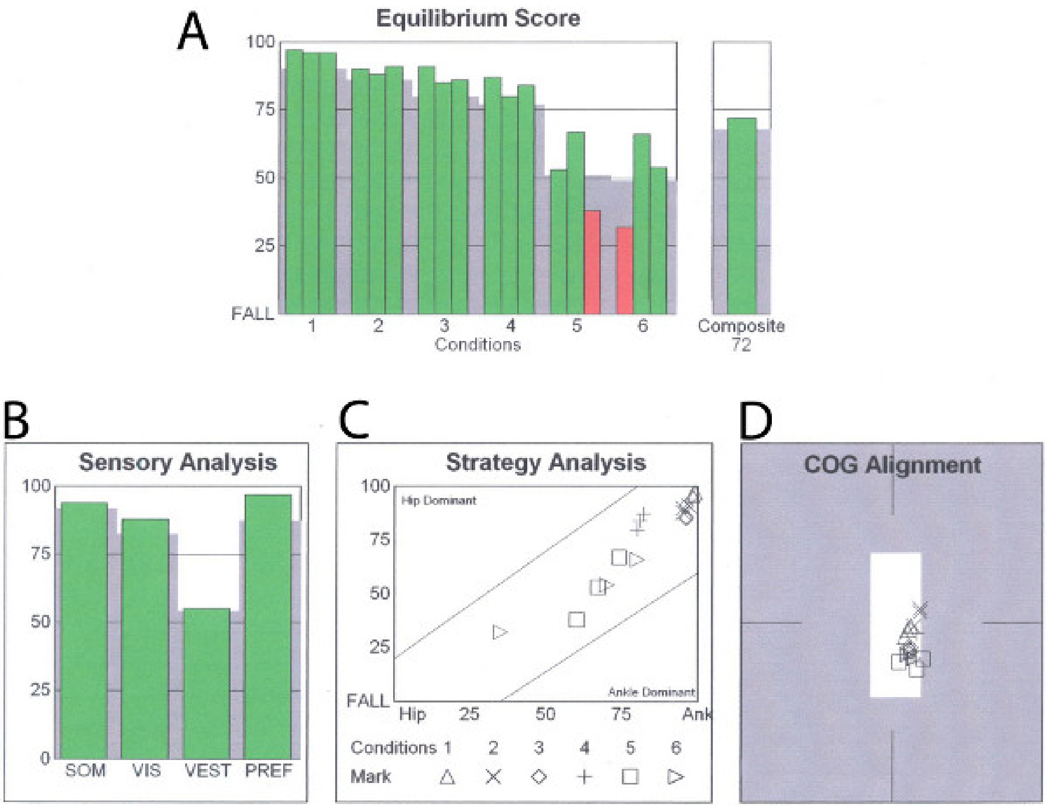

Figure 2. Representative results for one 66-year old participant with intermittent claudication on the Sensory Organization Test (SOT). The data are compared to an age-matched (60-69 years) normative dataset. Data are considered abnormal within the shaded areas, representing below the 5th percentile as compared to a normative database of age-matched participants with no symptoms or history of disequilibrium. **(A)** *Equilibrium score* for all 6 conditions, vertical axis represents SOT score (from 0-100, with 100 indicating perfect balance and 0 indicating a loss of balance) **(B)** *Sensory analysis* results indicating overall performance from the different sensory systems, vertical axis represents sensory ratio score (from 0-100, with 100 indicating perfect balance and 0 indicating a loss of balance) **(C)** *Strategy analysis* illustrating ankle vs. hip strategy dominance, the top right corner represents a full ankle strategy (values approaching 100) and the bottom left corner represents a full hip strategy (values approaching zero), while values in between represent a relative contribution from both strategies and **(D)** initial *COG alignment* prior to each SOT trial, with lateral movement along the horizontal axis and anterior-posterior movement along the vertical axis. Click here to view larger image.

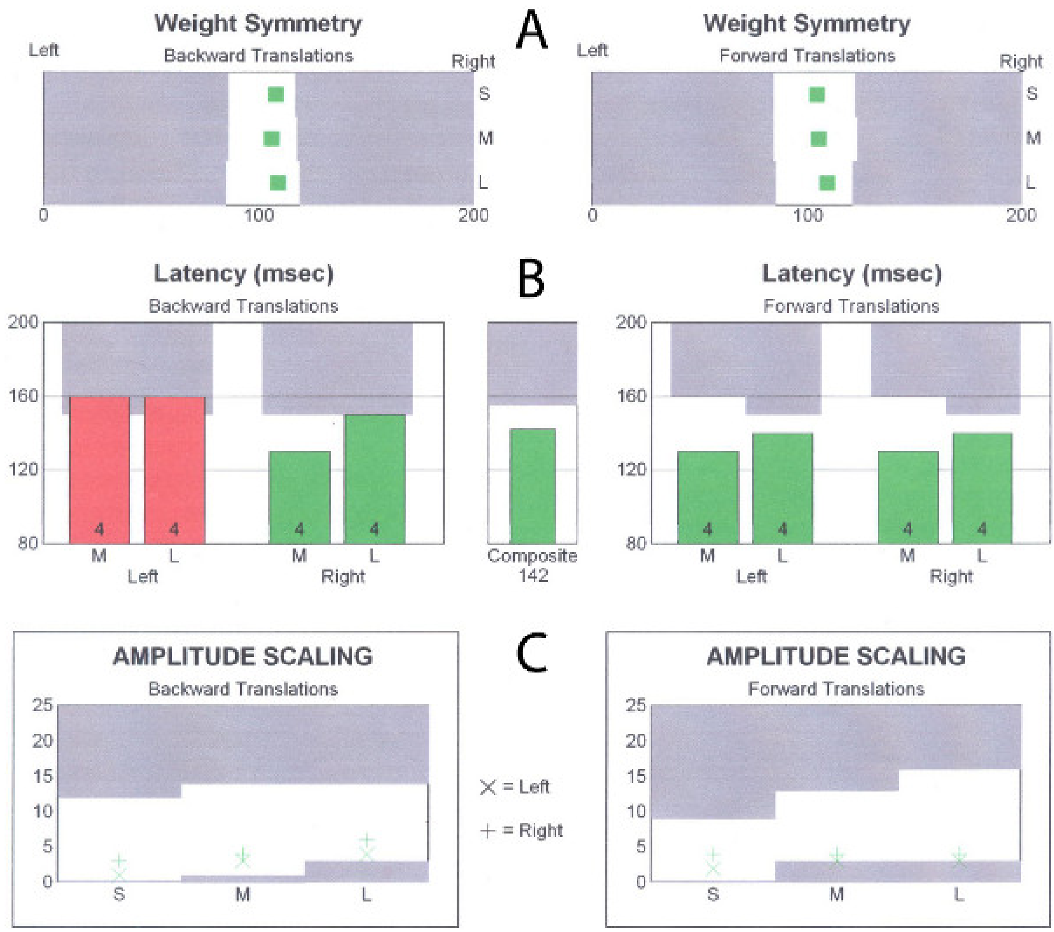

Figure 3. Representative results from one 66-year old participant with intermittent claudication on the Motor Control Test (MCT). The data are compared to an age-matched (60-69 years) normative dataset, as indicated by the shaded areas. Data are considered abnormal within the shaded areas, representing below the 5th percentile as compared to a normative database of age-matched participants with no symptoms or history of disequilibrium. All scores are evaluated for the left and right limbs independently. **(A)** *Weight symmetry* indicates weight distribution under the left and right legs prior to perturbation onset **(B)** *Latency scores* measure the time lapse between force plate translation on postural response **(C)** *Amplitude scaling* refers to the ability of the participant to generate a response strength that is appropriate for the magnitude of the perturbation (*e.g.* force plate translation). Click here to view larger image.

Discussion

The assessment of postural control is important in individuals who have a higher susceptibility to falls, often because of ageing or disease. Computerized dynamic posturography is a unique technique in that the sensory systems responsible for balance can be challenged through separate protocols that systematically differentiate between impairments[4]. The Sensory Organization Test (SOT) can identify when a person makes poor use of somatosensory, visual, or vestibular cues or relies on visual input even when it is inaccurate. For example, the *Sensory analysis* identifies when a person makes poor use of vestibular cues or when vestibular cues are unavailable. This is accomplished by analyzing the *Equilibrium* and *Strategy scores* when visual cues are absent (eyes closed) and somatosensory cues are inaccurate because of a sway-referenced support surface (condition 5). Such information would be particularly valuable for peripheral arterial disease as many claudicants unknowingly have vestibular dysfunction[9], which in turn compromises their balance and puts them at higher risk of falling. Moreover, because automatic postural responses are controlled by long-latency pathways involving the peripheral sensory and motor nerves (as measured with the MCT), claudicants are likely to demonstrate decreased response amplitudes and abnormal muscular activation. Therefore the SOT and MCT tests are particularly relevant sensorimotor tests that challenge balance in patients with intermittent claudication caused by peripheral arterial disease.

Some factors need to be considered when interpreting the findings from the sensory and motor protocols on the EquiTest. An abnormal *Equilibrium score* occurs when the value falls below the 5th percentile compared to the age-matched normative dataset. An abnormal SOT score is reported when the composite score **plus one** *Equilibrium score* fall below the 5th percentile. Results from at least one trial across all conditions must be included to calculate the composite score. The *Sensory analysis* is useful at diagnosing a sensory dysfunction, but should only be used as a heuristic, not a definitive, tool. An abnormal *Latency score* can occur if the latency following a large translation is slower than the age-matched normative dataset, and there is good agreement on a take-off point as determined by the multiple slope algorithms. Similarly, an abnormal *Latency* may arise if the response strength scores are abnormally low or if the participant is weight-bearing normally, but an accurate take-off point cannot be determined. In such circumstances, the automatic postural responses are considered to be absent or too slow.

A decline in performance, exhibited as worsening performance on trials 2 and 3 relative to the first trial, may be indicative of participant fatigue. Performance must deteriorate from trial 1 to trial 3 by at least two standard deviations more than the expected trial 1 to trial 3 variability in order to be classified as a true decline. Performance decline may be caused by fatigue, or an exacerbation of the participant's existing disease and/or symptoms, and is not related to the participant's understanding of the testing instructions. Anxiety could also affect performance adversely. A decline in performance affected by anxiety could be evidenced by declining abnormal scores; or if the first trial shows a normal score, but subsequent trials are abnormal. It is important to remember that some conditions (particularly 3-6 on the SOT) present an unusual situation for many participants. Thus the first trial represents a truly novel experience, after which time a person might become anxious or demonstrate a learning effect based on immediate prior experience.

The accuracy and fidelity of the data derived from the EquiTest is dependent upon several factors. Firstly, foot position on the dual force plate support surface determines the position of the COG relative to the center of force (COF) support. The COF refers to a single point where all the forces exerted by each leg independently are combined and thus represents the instantaneous muscle effort about the ankle joint. If the participant is standing with incorrect foot position, the x-y *COG alignment* will be inaccurate. Prior to each trial, the participant's initial COG position is illustrated on the display screen, and this should be checked to ensure proper foot positioning. However, as previously stated, if the *COG alignment* is off-center, but the feet are correctly positioned, they should not be readjusted. This would indicate the individual naturally stands with the COG offset relative to the center and is at higher risk of falling if a perturbation occurs in the same direction as the offset. If a person moves their feet (*i.e.* takes a step) during a trial or touches the visual surround or requires assistance from the investigator, it should be marked as a loss of balance. Care should be taken to reposition the feet after such an event. Secondly, if the harness is overly tight, it will independently stabilize the participant when their COG approaches the limits of stability. To check for harness pulling, the shear force traces during the SOT conditions can be scrutinized for a unidirectional, sustained deflection when the participant is 'suspended'. This would be evidenced as relatively large in amplitude, but low in frequency, shear forces that follow the COG sway. On the MCT, incorrect foot positioning is the primary source of error. For example, if both feet are positioned proportionately right of the center line, the *Weight symmetry score* will show that the right foot is bearing more body weight, when weight distribution is *de facto* symmetrical. When calculating the *Latency score*, several slope detection algorithms are used to determine the instance at which the COF starts to move rapidly following the onset of a perturbation (*i.e.* support surface translation). The latency 'quality factor' number reveals the number of algorithms that agreed on the same take-off point and thus reflects the reliability of the *Latency score*. Values of four (the maximum) are desirable, while values of two or less should be treated with caution and the COF traces should be visually examined. A zero value means that no algorithms reached agreement on a take-off point.

The SOT and MCT are routinely used as diagnostic tests, both clinically and for research, benefitting older adults and especially those with a history of falling, individuals suffering from dizziness, falls related to polypharmacy, patients with neurological or vestibular disorders, and patients with orthopedic injuries. However, caution should be taken when assessing patients with more debilitating orthopedic and/or musculoskeletal conditions. Previous studies with lower limb amputees[8-9,17] have revealed that the musculoskeletal deficits in some populations limit the interpretation of some results. For example, amputees are unable to generate an ankle strategy with a mechanical ankle-foot complex. As *Equilibrium* and *Strategy scores* are determined overall, not for each limb independently, reduced sway (and thus better scores) could be caused by a stiff prosthetic ankle, rather than above-average postural control[8,18]. On the MCT, the inability to generate sufficiently large and detectable active force responses with the affected limb results in no *Latency scores*. Therefore, care should be taken if incorporating EquiTest testing with certain patient groups with severely altered lower limb mechanics and/or unilateral function (*e.g.* lower limb amputees, stroke patients).

The EquiTest is a valuable objective measurement tool and has many applications in clinical and research settings. To complement the sensory tests, there are other protocols that test motor impairments, such as the Adaptation Test, Weight Bearing Squat, Limits of Stability, and Rhythmic Weight Shifting. Protocols that measure functional limitation impairments include the Unilateral and Tandem stance tests, Sit to Stand and Walking Tests. The EquiTest may also be used as an individualized training tool for balance programs, and benefits the user by providing detailed, real-time visual biofeedback. Many of these tests use an additional long force plate with accessories (*e.g.* wooden steps/stairs, rocker board, unstable compliant surface). Other data acquisition systems can be synchronized with the EquiTest equipment; for example, muscle activation profiles can be measured prior to and in response to postural perturbations with electromyographic analysis. Future applications involving the EquiTest may evaluate the effectiveness at using real-time visual biofeedback for improving balance and function on daily tasks compared to more traditional balance programs.

Balance assessment and individualized training is important for many population groups who suffer with chronic postural impairments related to ageing or disease. Using computerized dynamic posturography, the EquiTest presents a unique method for analyzing and interpreting postural corrections to perturbations. It is a valuable tool intended to supplement other diagnostic methods (such as the ABPI in patients with peripheral arterial disease) by objectively assessing impairments and measuring the associated functional limitations. A comprehensive analysis would enable clinicians and healthcare practitioners to design appropriate targeted interventions for improving balance performance and reducing the potential for future falls.

Disclosures

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